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DEPARTMENT OF COMMERCE - BUREAU OF MINES

PREVENTION OF ACCIDENTS WITH EXPLOSIVES IN THE TRI-STATE ZINC AND LEAD ORE PRODUCING DISTRICT

By S. P. Howell*

Introduction

Premature explosions and misfires are responsible for a large majority of the accidents resulting from the use of explosives in the Tri-State zinc and lead ore producing district. Accident Prevention Bulletin No. 56, issued by the Tri-State Zinc and Lead Ore Producers Association, shows that 6 fatal accidents in 1925 and 7 in 1926 were caused by handling high explosives and detonators. Analytical study of these accidents shows that 6 of the fatalities were due to premature explosions, 3 occurred while holes were being loaded, 2 were caused by picking into failed shots, and 1 was the result of a dormant shot. However, accidents that occur while a hole is being loaded are premature-explosion accidents in the broader sense, while those classed as "picked into failed shots" and "explosion of dormant shot" are really due to misfires; hence 12 of the 13 fatalities may be ascribed to one or the other of these two general types of accident. In view of this preponderance, the following discussion of means of preventing explosives accidents will be confined chiefly to those caused by premature explosions and misfires.

The observations concerning blasting practice upon which this paper is based were made in March, 1927, during a visit to the Tri-State district while the author was assisting in an accident-prevention campaign. Arrangements made by R. V. Ageton, accident-prevention engineer and the courtesy of mine officials enabled him to inspect 10 mines in the district with F. H. Nesbit, assistant accident-prevention engineer, and to confer with other accident-prevention engineers, superintendents, ground bosses, powder men and machine men, individually and in groups. The full cooperation accorded by each of these individuals and groups is gratefully acknowledged.

CONDITIONS SURROUNDING THE USE OF EXPLOSIVES IN THE TRI-STATE DISTRICT

General Practice

The shafts of the mines visited are 220 to 348 feet deep. The principal ores mined contain galena and sphalerite in a flint gangue. The minerals are either disseminated or occur in veins, veinlets, or vugs.

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Ore is mined by the underhand-stoping method and the different types of blasting may be classed as "drift," "pull drift," "slabbing," stope and "split," loading in chambers or loading "slick," "squibbing" (chambering), and block holing.

The so-called "drifts" are driven at or near the top of the ore body and are the pioneering cuts above the stopes. The "drifts" are not as accessible as the "pull drifts," but holes can often be placed to greater advantage because of the width of the free face.

The "pull drifts" correspond to the main drifts in other metal-mining districts. One such "pull drift," 6 feet by 6 feet was blasted with fourteen 6-1/2-foot holes using the 4-hole pyramid cut. The 3 lifters each contained two "shots" (primers). One 50-pound case of 60 per cent gelatin dynamite was used in the 4 cut and 4 reliever holes, and one 50-pound case of 40 per cent gelatin in the 3 back holes and 3 lifters. The holes were wet.

The usual depth of "drift" holes and "pull drift" holes is 9 feet.

Stope rounds are used on or near the bottom of the stope and normally vary from 1 to 5 holes per round, are up to 16 feet deep, and their placement depends largely on the height and shape of the unbroken rock. The lower holes point slightly downward. Stope holes are "squibbed" or enlarged by preliminary smaller dynamite charges if the burden requires it or if the rock can not be otherwise broken without forming bowlders. Otherwise, holes are loaded "slick," that is, without being squibbed.

A very high stope may require holes called "splitters" between the drift and stope holes. These splitters are drilled, squibbed, and blasted similar to stope holes. Many stope and splitter holes are wet, although certain mines have few wet holes. Splitter holes are squibbed if the burden is great or the rock difficult to blast.

The time between the preliminary squibbing shots and between the final squibbing shot and the primary blast was standardized at 24 hours in one mine visited.

The larger bowlders are broken by blasts in short block holes.

Because of crevices and cavities in the rock the drift holes, splitter holes, and stope holes are frequently ragged, and unless care is taken in charging, the cartridges may fall into these openings. In drilling, the rock often crumbles easily, especially at and near the collar of the holes, so that the collars are much enlarged. For example, the collar of one hole was oval in section, 5 inches wide, and 12 inches long; other holes were smooth throughout and could be easily charged by simply pushing the cartridge "home." In most mines the large percentage of ragged holes necessitates the "leading in" of single cartridges and of the "shot" by placing them on the copper spike of a copper-ferruled pine tamping bar. When thus placed in position the cartridges are tamped firmly with the wooden end of the tamping bar.

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At the mines visited powder men or machine men charge the holes and spit the fuse. Cartridges are usually slit once in order that a high density of loading can be procured.

The mines of this district generally use 1-1/4-inch hollow drill steel, though one mine uses 1-1/8-inch, and some mines use some 1-inch as well as other sizes. In one mine the steel used for drilling stope and "splitter" holes is 2 to 20 feet long, by 2-foot increments, while the gage diameter of the drill bit varies from 2-3/4-inches for the starter to 1-5/8 inches for the finisher by 1/8-inch increments. For shorter holes the finisher has a gage of 2-1/2 inches. Water drills are used, and wet drilling prevails.

Screen goggles are used by some machine men and their helpers while starting and blowing out holes.

The Explosives

Gelatin, extra gelatin, and ammonia dynamites of 33 and 35 per cent grades, and gelatin dynamites of 25, 30, and 40 per cent grades in 1-1/4-inch diameter are commonly used. However, some 20-60 per cent gelatin dynamite is used, the latter in cut holes and relievers in "pull drifts," and a very small proportion of the explosive is in 1-1/8-inch diameter cartridges. Explosives are used fresh, deliveries being made at not more than one-month intervals. The district is particularly fortunate in this respect, and the practice is a direct result of three of the four manufacturers who supply explosives to the district having plants nearby. The explosive is delivered 1, 2, 3, or even 6 times a week from manufacturers' or jobbers' distributing magazines to some individual mines. The largest delivery to one mine that was noted was sixty 50-pound cases. Gelatin dynamite is commonly used in wet holes, in places where there was inadequate ventilation, for squibbing, and at some mines for "shots" or primers when the main charge is ammonia dynamite. If deliveries are frequent the explosives are commonly brought by the manufacturer or jobber to the collar of shaft, where they are promptly taken underground in the ore "cans," each accommodating about ten 50-pound cases. They are stored in a dry place as far from the shaft and working place as is feasible. Larger deliveries are made to outside magazines from which daily deliveries are made underground. The district uses approximately 8,000,000 pounds of high explosives annually.

The Detonators

No. 6 detonators are used in "shots" or primers of ammonia dynamite and at some places in "shots" of gelatin dynamite. Some mines use No. 8 detonators exclusively in gelatin dynamite "shots".

The Fuse

Fuse with a rated burning speed of 40 seconds per foot is extensively used, but in some mines the fuse used has a rated burning speed of 30 seconds. Both brands employed are designed for use in very wet work. Fuse was received

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in coils, each containing two 50-foot lengths. It was commonly measured by a standard length of fuse, although a scale cut on a bench was sometimes used. Fuse used in dependent shots was trimmed about 5 inches. Fuse was spit with a carbide lamp. Blasting during the shift is infrequent and is discouraged.

Capped fuse is commonly made up at primer stations either above ground or underground by crimping the detonator on the 6-foot to 10-foot measured fuse with hand crimpers. One bench crimper was observed in use underground.

Primers ("Shots")

"Shots" are made in a variety of ways. Usually the detonator is placed in one end of the cartridge so as to be isolated from the copper spike of the tamping bar, which is inserted in the opposite end of the "shot". Where no "shot tube" is used, the fuse is secured in place by tying the loosened paper of one end of the cartridge around it with cord (see fig. 1) or by lacing the fuse through the cartridge. Where the McLaughlin & Anderson "shot tube" (see fig. 1) is used the detonator is commonly placed in the end of the cartridge near the wooden plug. The hole in the center of the plug does not go through the plug by 1/4 inch, thus isolating the detonator from the copper spike of the tamping bar. When the Chica type of "shot tube" (see fig. 1) is used the detonator is commonly placed in the far end of the cartridge so that the detonator is at least 4 inches from the copper spike of the tamping bar. The writer's observation was that the fuse was laced through less than half of the "shots" used in the mines visited. In all instances noted save one the fuse emerged from the side of the end of the "shot", permitting the spike to be placed in the opposite side of the end of the "shot" protecting the fuse from the tamping bar. In all holes of primary blasts the detonator was pointed toward the bottom of the holes. In all blasts noted in which there were dependent shots the primer was placed near the bottom of the hole, thus preventing the fuse from being cut by an overbreak. In squibbing and in single stope holes the primer was at or near the top of the charge.

Many powder men prefer to use gelatin dynamite in "shots" because these are easily made with plastic explosive.

Stemming

Stemming was not used in any holes. One mine reported unfavorably on the use of stemming after a trial. It is noted, however, that two of the larger mining companies plan to use stemming in all of their mines. This is, of course, the best practice.

PREVENTING MISFIRES

As previously noted, 3 fatal accidents in two years were caused by misfires. These can not be attributed to aged and therefore insensitive explosives because explosives in this district are very generally used in a fresh condition. The fuse is likewise of high quality. The writer believes that when fuse is used misfires can be largely, if not wholly, prevented in any metal mine using high-grade explosives and blasting supplies (a) if proper standard primers (shots) are adopted; (b) if care is used in preparing the charge and preparing and charging

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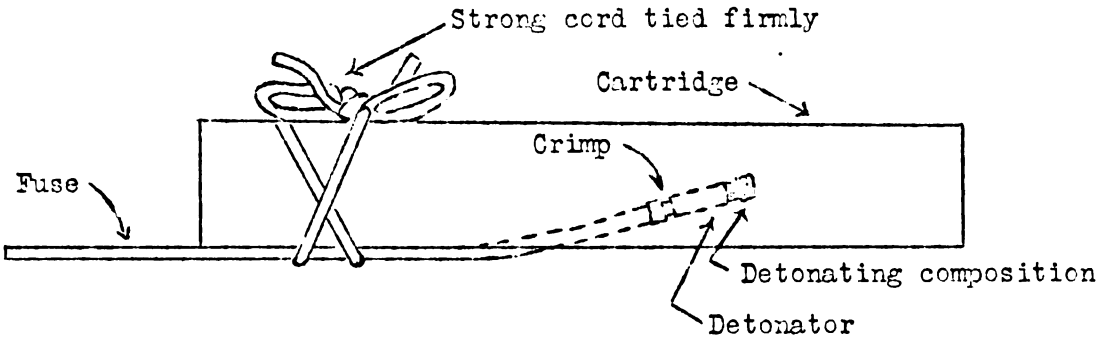
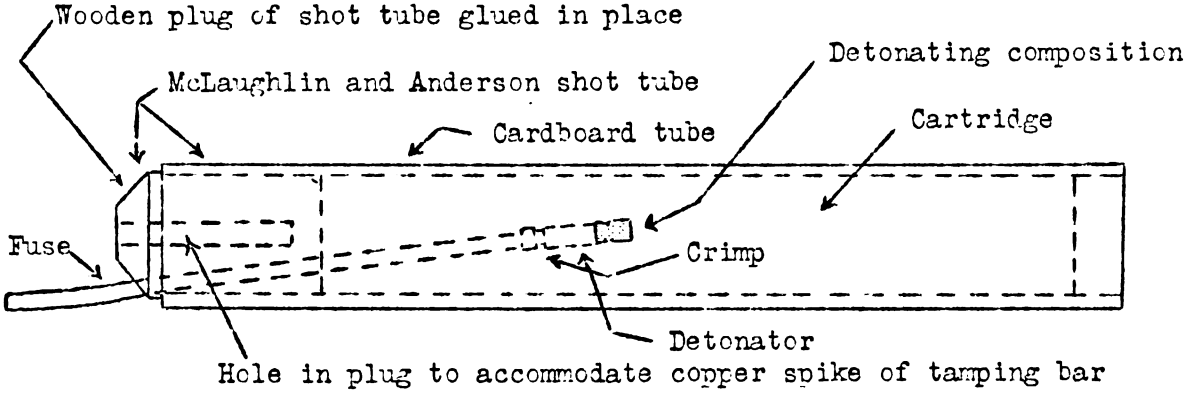
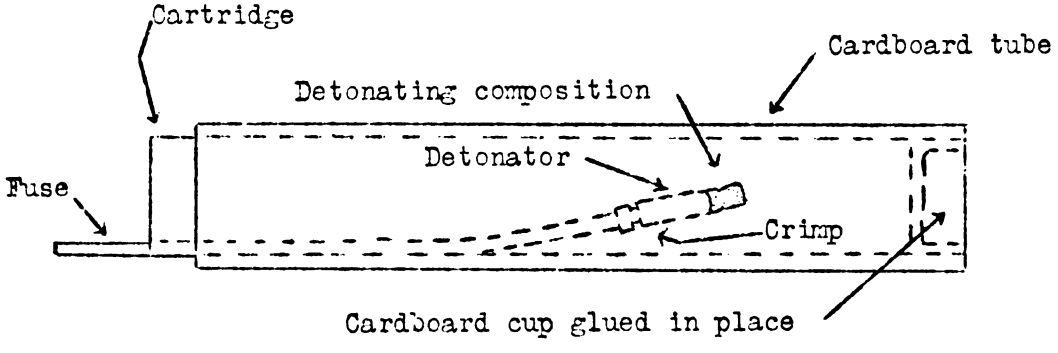


Primer (Shot) without shot tube



Primer (Shot) made with McLaughlin and Anderson shot tube



Primer (Shot) made with Chicago shot tube

FIGURE 1. - PRIMERS ("SHOTS")

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the holes; (c) if stemming is used; (d) if No. 8 detonators or electric detonators are used in primers made with gelatin dynamite which is not fresh; and (e) if "shots" in dependent holes are placed near the bottom of the charge.

In this district, where a substantial proportion of the holes are ragged or intercept crevices or pockets, the use of "shot tubes" (see fig. 1) seems desirable as a precaution against misfires. Several hundred thousand "shot tubes" have been successfully used. At a given mine the "shot" should be standardized so that these conditions prevail: A single type of tube; fuse not laced through cartridges; fuse emerging from side of end of cartridge; "business" end of detonator in center line of cartridge; detonator points toward bottom of hole; at least 4 inches between detonator and copper spike of tamping bar; and the inside diameter of tube to fit primed cartridge firmly but not loosely or tightly. These conditions are fulfilled if "shots" are made as shown in Figure 1.

The end of the fuse to be inserted in the detonator should be cut off squarely with a sharp knife and the freshly cut end inserted in the detonator so as to touch the detonating composition gently.

Detonators may be crimped on the fuse with hand crimpers which are in good condition. The greatest uniformity in crimping obtains, however, if bench crimpers are used and operated by a trained man especially assigned to the job.

For use in wet work, the fuse at, and for a few inches above, the detonator should be covered with a waterproofing compound, such as P. and B. paint, Kapseal, and Celakap but not with oil or liquid grease.

In very wet work delay electric detonators with enameled copper legs should be used in dependent shots.

The greatest assurance against misfires obtains when electric detonators or delay electric detonators are used.

Before being charged the holes should be cleaned of loose material. This may be done by blowing out the residual cuttings or by scraping out smooth holes. Loose material in a borehole may promote misfires by so separating cartridges that the whole charge is not detonated. A high charging density can be attained by firmly tamping the charge with short firm taps with a wooden tamping bar. Several cartridges of moist, fine stemming, such as moist plastic clay, should be used in each hole of primary blasts. This prevents misfires by securing the explosive in place. In another mining district the writer has observed cartridges on the muck pile which had been pulled out of a hole by the blast from a previously fired hole of a round, even though two cartridges of poorly tamped stemming were in the hole. In this case the fuse of the dependent hole had not been spit. Had it been spit the ejected cartridges would have been buried in the muck pile. Such blasts would, on occasion, with unstemmed holes, displace or eject the "shot" or primer and cause a misfire. Among its other advantages stemming should be used to reduce misfires.

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In general, No. 8 detonators are recommended for use with "shots" or primers that are made with gelatin dynamite, but under the specially favorable conditions obtaining in many of the mines of the Tri-State district, No. 6 detonators appear to be wholly satisfactory for use with gelatin "shots". These special conditions are: The use of fresh gelatin dynamites; the storage of the detonators above ground in cool, dry places; and the use of "shot tubes" in holes that are difficult to charge.

"Shots" should be placed far enough into the charge of a dependent hole so that, should the hole be cut off, the powder core of the fuse will be burning beyond the point of cut off.

PREVENTING ACCIDENTS WHILE CHARGING AND FROM PREMATURE EXPLOSION

Premature explosions may result from improper methods of opening boxes of explosives. They should be opened with wooden tools, such as wooden wedges and wooden mallets.

Assuming that fresh explosives and high-grade blasting supplies such as are used in this district are employed, accidents during charging and from premature explosion can be prevented by care in charging by a standard method. The use of "shot" tubes makes it possible to place the "shot" in safety, for they not only prevent the "shot" from falling into crevices and chambers or getting crosswise of the hole but hold the detonators in place in the cartridge. At a given mine a standard "shot" should be adopted and used in all "drift," stope, and "splitter" holes. In mines free from ragged holes "shot tubes" need not be used. In any event, the fuse should be so secured that the detonator is anchored in place in the center line of the cartridge and at least 4 inches from the copper spike when placed in the cartridge. The "shot" and the cartridges immediately following it should be placed in the hole carefully. Other cartridges should be pressed home firmly but never forcibly. The spiked end of the tamping bar should be used only for leading in the cartridges and the "shot"; tamping should be done only with the wooden end of the tamping bar. Explosives should be protected from sparks and flames; thus, fires, open lights or smoking should not be permitted near explosives. The holes should be charged just before firing time. Stemming should be used. From the time the charging of holes is begun until they are fired all other work near the holes should cease. Only those required to charge and tamp the holes should be permitted near the holes, and they only while engaged in the work. No matter how remote the probability of a premature explosion, the minimum number of persons should be in the danger zone.--Information Circular, Bureau of Mines, Department of Commerce.

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